FIGS. 5A and 5B depict an embodiment with a multiple zone folded coaxial resonator **300** overlying the cover plate **106**. The multiple zone coaxial resonator **300** includes an inner return cylinder **310**, an intermediate return cylinder **315**, an outer return cylinder **320** and a disk-shaped cap **322**. The inner return cylinder **310** and outer return cylinder **320** extend from the disk-shaped cap **322** to the cover plate **106**. The intermediate return cylinder **315** extends downwardly from the cap **322** and has a bottom edge **315***a* separated from the cover plate **106** by a gap G**1**. An inner zone driven cylinder **330** is surrounded by the intermediate return cylinder **315**. The inner zone driven cylinder **330** has a top edge **330***a* separated from the disk-shaped cap **322** by a gap G**2**. An outer zone driven cylinder **335** surrounds the intermediate return cylinder **315**. The outer zone driven cylinder **335** has a top edge **335***a* separated from the disk-shaped cap **322** by a gap G**3**. In the illustrated embodiment, the gaps G**2** and G**3** are of different sizes for ease of illustration, although in general they may be of the same size.

The inner zone driven cylinder **330** is coupled at its top edge **330***a* to an inner zone RF generator **350** through RF feed conductors **360** surrounded by shielding **365** contacting the disk-shaped cap **322**. The outer zone driven cylinder **335** is coupled at its top edge to an outer zone RF generator **355** through RF feed conductors **370** surrounded by shielding **375** contacting the disk-shaped cap **322**. A controller **337** governs the ratio between the RF output power levels of the inner zone RF generator **350** and the outer zone RF generator **355**. The controller **337** controls the radial distribution of plasma ion density among the inner and outer zones of the chamber **100** coinciding with the inner zone driven cylinder **330** and the outer zone driven cylinder **335**.

As depicted in FIGS. **5**A and **5**B, the RF feed conductor **360** contacts the top edge **330***a* at plural uniformly spaced points **331**, while the RF feed conductor **370** contacts the top edge **335***a* at plural uniformly spaced points **336**.

As shown in FIG. **5**B, an inner annular zone **380** of the cover plate **106** supports toroidal channels **150-1** through **150-4**, while an outer annular zone **385** of the cover plate **106** supports toroidal channels **150-5** through **150-8**. In the illustrated embodiment there are four uniformly spaced toroidal channels in each zone **380**, **385**. Any other suitable number of toroidal channels may be provided in each zone. For example, FIG. **5**B depicts in dashed line the optional inclusion of four additional toroidal channels in the outer zone **385**. Each of the toroidal channels **150-1** through **150-8** may be of the structure described above with reference to FIGS. **1**A-**1**D. In the illustrated embodiment, the inner zone **380** lies between the inner return cylinder **310** and the intermediate return cylinder **315**, while the outer zone **385** lies between the outer return cylinder **320** and the intermediate return cylinder **315**.

As in the embodiment of FIGS. **1**A-**1**D, in FIG. **5**A a gas injection plate **116** on the bottom surface of the cover plate **106** includes an internal gas manifold **118** having an array of gas injection orifices **120** facing the workpiece support surface **112**. A gas supply conduit **122** coupled to the internal gas manifold **118** extends upwardly from the gas injection plate **116**. A pair of coolant circulation conduits **124** extend to internal coolant circulation passages **126** within the cover plate **106**. The gas supply conduit **122** extends through the interior of the inner return cylinder **310** to an external gas supply. The interior of the inner return cylinder **310** may be a field-free region. A pair of coolant circulation conduits **124** extend through the interior of the inner return cylinder **310** from an external coolant supply, to coolant passages **126** within the cover plate **106**.

Embodiments may be employed for sequential processing, in which the gas distribution plate **118** of FIG. **1** is divided into four separate sections (e.g., quadrants) corresponding to the four toroidal channels **150** of FIG. **1**. Each quadrant of the gas distribution plate is supplied with a different process gas, so that each toroidal channel **150** provides a plasma of different species. The workpiece support surface **112** may be rotatable, so that different sections (e.g., quadrants) of the workpiece are exposed to the different plasmas at different times. While such sequential processing is described here with reference to an equal number of toroidal channels and sections of the gas distribution plate **118** in which the number is four, any other suitable number of toroidal channels and gas distribution plate sections may be employed.

While the foregoing embodiments have been described with reference to a coaxial resonator (**130**, **230** or **300**) having an effective length corresponding to a wavelength at the RF power generator frequency, it is not required that the generator wavelength exactly match the coaxial resonator length. If the RF power generator wavelength differs from the coaxial resonator length, then an impedance matching function performed by the coaxial resonator **130**, **230** or **300** compensates for the difference.

Each of the embodiments described can provide one or more of the following characteristics: ability to generate a high density plasma with minimum capacitive effects, which minimizes plasma ion energy at metal surfaces adjacent the plasma sheath; a grounded conductive chamber ceiling, to which process gases and coolant flow may be provided through a field-free region, and which provides a uniform RF ground reference for an optional RF bias power generator; and, immunity from influence by chamber grounds, because the plasma current closes a current loop on its own.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A plasma reactor comprising:

a processing chamber comprising a ceiling and a workpiece support;

a resonator having an axis of symmetry and comprising:

inner and outer return cylinders and an intermediate return cylinder between said inner and outer return cylinders,

inner and outer RF-driven cylinders adjacent inner and outer surfaces, respectively, of said intermediate return cylinder,

said inner and outer return cylinders and said inner and outer RF-driven cylinders contacting said ceiling; and

inner and outer pluralities of reentrant conduits on a side of said ceiling external of said processing chamber, said inner and outer pluralities of reentrant conduits disposed, respectively, in inner and outer concentric zones of said ceiling.

2. The plasma reactor of claim **1** wherein each of said plural reentrant conduits extends in a radial direction.

3. The plasma reactor of claim **1** further comprising first and second RF power generators coupled to said inner and outer RF-driven cylinders, respectively, and a controller connected to said first and second RF power generators.

4. The plasma reactor of claim **2** wherein said ceiling comprises, for each respective reentrant conduit of said inner and outer pluralities of reentrant conduits, a pair of ports extending through said ceiling and coupled to opposite ends of the respective reentrant conduit.